

AD-A065 852

FOREIGN TECHNOLOGY DIV WRIGHT-PATTERSON AFB OHIO
THE EFFICIENCY OF HEAT CONDUCTIVITY OF HONEYCOMB FILLERS, (U)
SEP 78 G N ZAMULA

F/6 20/13

UNCLASSIFIED

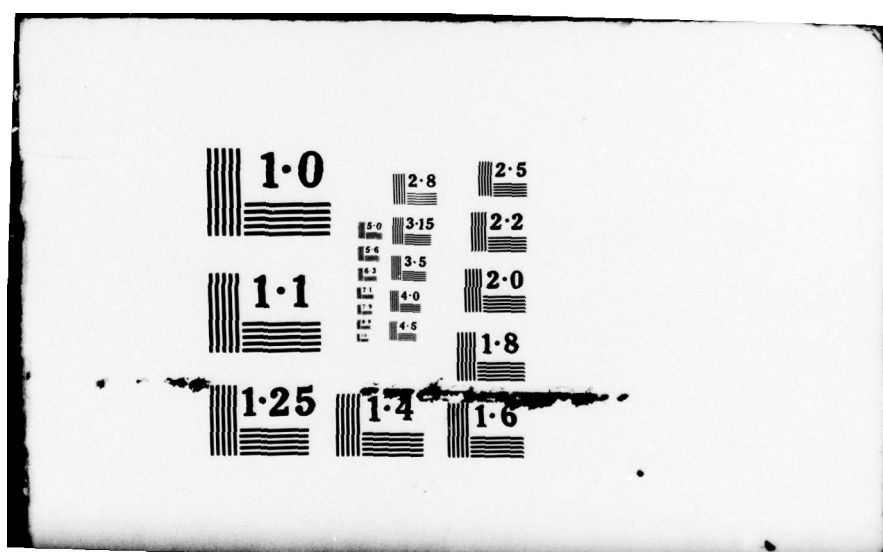
FTD-ID(RS)T-1631-78

NL

1 OF 1
ADA
065852



END
DATE
FILMED
4-79
DDC



AD-A065852

FOREIGN TECHNOLOGY DIVISION



THE EFFICIENCY OF HEAT CONDUCTIVITY OF HONEYCOMB FILLERS

By

G. N. Zamula



78 12 27 250

Approved for public release;
distribution unlimited.



EDITED TRANSLATION

FTD-ID(RS)T-1631-78

27 September 1978

MICROFICHE NR: *AD-78-C-001295*

THE EFFICIENCY OF HEAT CONDUCTIVITY OF
HONEYCOMB FILLERS

By: G. N. Zamula

English pages: 8

Source: Issledovaniya po Teploprovodnosti,
Minsk, 1967, pp. 255-261

Country of Origin: USSR

Translated by: Charles T. Ostertag, Jr.

Requester: FTD/TQTA

Approved for public release; distribution unlimited.

ACCESSION FOR	
RTD	White Carded <input checked="" type="checkbox"/>
DDC	Buff Section <input type="checkbox"/>
ENHANCED	<input type="checkbox"/>
JUSTIFICATION	
BY	
DISTRIBUTION AVAILABILITY CODES	
MAIL	AVAIL. REQ. BY SPECIAL
<i>A</i>	

THIS TRANSLATION IS A RENDITION OF THE ORIGINAL FOREIGN TEXT WITHOUT ANY ANALYTICAL OR EDITORIAL COMMENT. STATEMENTS OR THEORIES ADVOCATED OR IMPLIED ARE THOSE OF THE SOURCE AND DO NOT NECESSARILY REFLECT THE POSITION OR OPINION OF THE FOREIGN TECHNOLOGY DIVISION.

PREPARED BY:

TRANSLATION DIVISION
FOREIGN TECHNOLOGY DIVISION
WP.AFB, OHIO.

FTD -ID(RS)T-1631-78

Date 27 Sept 19 78

U. S. BOARD ON GEOGRAPHIC NAMES TRANSLITERATION SYSTEM

Block	Italic	Transliteration	Block	Italic	Transliteration
А а	<i>А а</i>	A, a	Р р	<i>Р р</i>	R, r
Б б	<i>Б б</i>	B, b	С с	<i>С с</i>	S, s
В в	<i>В в</i>	V, v	Т т	<i>Т т</i>	T, t
Г г	<i>Г г</i>	G, g	У у	<i>У у</i>	U, u
Д д	<i>Д д</i>	D, d	Ф ф	<i>Ф ф</i>	F, f
Е е	<i>Е е</i>	Ye, ye; E, e*	Х х	<i>Х х</i>	Kh, kh
Ж ж	<i>Ж ж</i>	Zh, zh	Ц ц	<i>Ц ц</i>	Ts, ts
З э	<i>З э</i>	Z, z	Ч ч	<i>Ч ч</i>	Ch, ch
И и	<i>И и</i>	I, i	Ш ш	<i>Ш ш</i>	Sh, sh
Й й	<i>Й й</i>	Y, y	Щ щ	<i>Щ щ</i>	Shch, shch
К к	<i>К к</i>	K, k	Ъ ъ	<i>Ъ ъ</i>	"
Л л	<i>Л л</i>	L, l	Ы ы	<i>Ы ы</i>	Y, y
М м	<i>М м</i>	M, m	Ь ь	<i>Ь ь</i>	'
Н н	<i>Н н</i>	N, n	Э э	<i>Э э</i>	E, e
О о	<i>О о</i>	O, o	Ю ю	<i>Ю ю</i>	Yu, yu
П п	<i>П п</i>	P, p	Я я	<i>Я я</i>	Ya, ya

*ye initially, after vowels, and after ъ, ь; e elsewhere.
When written as ë in Russian, transliterate as yë or ë.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	sinh ⁻¹
cos	cos	ch	cosh	arc ch	cosh ⁻¹
tg	tan	th	tanh	arc th	tanh ⁻¹
ctg	cot	cth	coth	arc cth	coth ⁻¹
sec	sec	sch	sech	arc sch	sech ⁻¹
cosec	csc	csch	csch	arc csch	csch ⁻¹

Russian English

rot curl
lg log

THE EFFICIENCY OF HEAT CONDUCTIVITY OF HONEYCOMB FILLERS

G. N. Zamula

The use of multilayer panels with a honeycomb filler in constructions which operate at high temperatures requires a calculation of effective heat conductivity of the filler, taking into account radiant heat exchange, which plays a significant role here. In work [1] an analysis is made of asymmetric aerodynamic heating and effective heat conductivity of a thin-wall panel with a circular cylindrical filler. The solution was constructed in a linearized formulation under the assumption of constancy of the nuclei of integro-differential equations, describing heat exchange in a honeycomb cell. We obtained the solution of a problem for different forms of a thin-walled cylindrical honeycomb filler when it is functioning in a system of a multilayer panel with absolutely black radiating surfaces on the basis of exponential approximation of the nucleus. An optimal form of filler cell is found depending on the dimensionless parameters which determine the process.

A cylindrical honeycomb filler is formed by identical cells which are adjacent to each other and which are made in the form of thin-walled hollow cylinders of different form in a plane with generatrices which are perpendicular to the plane limiting surfaces, which further are considered isothermic. Figure 1 gives an example of a honeycomb filler, the bases of the cells of which are true hexagons.

A honeycomb cell, thermally insulated on the side surface, is shown in Figure 2, where L and F - length of the nonconcave contour and area of the upper and lower bases of the cell with temperatures T_1 and T_2 respectively. The bases radiate according to the law of an absolutely black body, and the walls - ideally gray with a degree of blackness ϵ . We disregard heat exchange with the diathermic medium within the cell. The temperatures and radiant flows for a cell of arbitrary form in a plane will be averaged for each section parallel to the bases and the problem considered as unidimensional, which corresponds precisely to reality in the case of a round cylindrical filler and a filler in the form of an infinite set of parallel walls (axisymmetric and plane case).

With the accepted assumptions the equation of heat conductivity in a filler with consideration of heat radiation has the form

$$\frac{d^2 t(\xi)}{d\xi^2} - \sigma q(\xi) = 0; \quad (1)$$

the integral equation of radiant heat exchange

$$\begin{aligned} \frac{q(\xi)}{\epsilon} = & t^s(\xi) - K(\xi) - t_2^s K(1-\xi) - \\ & - \int_0^\xi \left[t^s(\eta) - \frac{1-\epsilon}{\epsilon} q(\eta) \right] \varphi(\xi-\eta) d\eta - \\ & - \int_\xi^1 \left[t^s(\eta) - \frac{1-\epsilon}{\epsilon} q(\eta) \right] \varphi(\eta-\xi) d\eta; \end{aligned} \quad (2)$$

boundary conditions:

$$t(0) = 1; \quad t(1) = t_2, \quad (3)$$

where it is designated

$$t = \frac{T}{T_1}; \quad \xi = \frac{z}{H}; \quad q = \frac{q_{\text{res}}}{c_0 T_1}; \quad \sigma = \frac{c_0 T_1^3 H^2}{\delta \lambda};$$

$K(\xi)$; $K(1-\xi)$ - coefficients of irradiance of an element of the cylindrical surface of the filler at a distance ξ from the upper base of the cell by the upper and lower bases respectively;

$\varphi(r) = -\frac{dK(r)}{dr}$ - mutual coefficient of irradiance of two elements of the cylindrical surface at a distance r from each other.

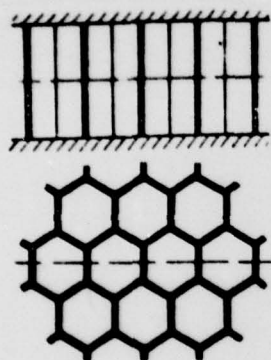


Figure 1. Hexagonal honeycomb filler.

The function $K(\xi)$, which is fading rapidly with an increase of ξ , for cells of arbitrary form in a plane we will approximate by the exponential function

$$K(\xi) = \frac{1}{2} \exp(-2l\xi), \quad (4)$$

where $l = \frac{LH}{4F}$ - dimensionless geometric parameter. In the case of a round cylindrical filler

$$l = \frac{H}{D}, \quad K(\xi) = \frac{1}{2} \exp\left(-2 \frac{H}{D} \xi\right)$$

we obtain the known approximation of work [2], and with a filler

in the form of a set of parallel walls -

$$l = \frac{H}{2a}, \quad K(\xi) = \frac{1}{2} \exp\left(-\frac{H}{a} \xi\right).$$

A comparison of the precise coefficients of irradiance $K(\xi)$ and their first derivatives, which for these two cases can be obtained readily by the differential method (see [3], and also [2]), with those calculated according to formula (4) is shown in Figure 2.

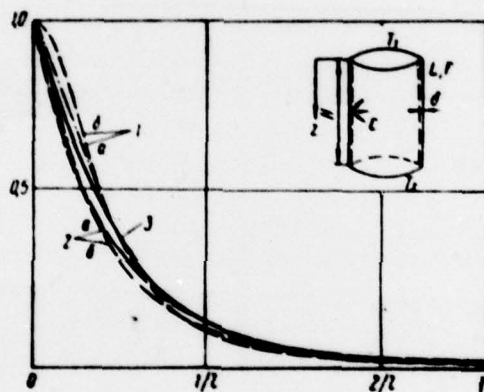


Figure 2. Comparison of the approximating function $\exp(-2l\xi)$ (3) with the precise angular coefficients $2K(\xi)$ (2) and $\frac{1}{l}K'(\xi)$ (1): a - for a round cylinder, approximation of work [2]; b - for parallel walls.

After substitution of (4) into (2) the integral equation (2) is replaced by the equation

$$\begin{aligned} \frac{q(\xi)}{\epsilon} = r^s(\xi) - \frac{1}{2} \exp(-2l\xi) - \frac{l_2^2}{2} \exp[-2l(1-\xi)] - \\ - l \int_0^1 \left[r^s(\eta) - \frac{1-\epsilon}{\epsilon} q(\eta) \right] \exp[-2l(\xi-\eta)] d\eta - \end{aligned}$$

$$-l \int_0^1 \left[t^4(\eta) - \frac{1-\varepsilon}{\varepsilon} q(\eta) \right] \exp[-2l(\eta - \xi)] d\eta, \quad (5)$$

which after the appropriate transformations can be reduced to the differential

$$\frac{d^2 q(\xi)}{d\xi^2} - 4\varepsilon t^2 q(\xi) = \varepsilon \frac{d^2 [t^4(\xi)]}{d\xi^2} \quad (6)$$

with boundary conditions:

$$\begin{aligned} \frac{q(0)}{\varepsilon} &= \frac{1}{2} - \frac{t_2^4}{2} \exp(-2l) - \\ &- l \int_0^1 \left[t^4(\eta) - \frac{1-\varepsilon}{\varepsilon} q(\eta) \right] \exp(-2l\eta) d\eta, \\ \frac{q(1)}{\varepsilon} &= \frac{t_2^4}{2} - \frac{1}{2} \exp(-2l) - \\ &- l \int_0^1 \left[t^4(\eta) - \frac{1-\varepsilon}{\varepsilon} q(\eta) \right] \exp[-2l(1-\eta)] d\eta. \end{aligned} \quad (7)$$

The problem is reduced to two differential equations of the 2nd order (1) and (6) or their equivalent equation of the 4th order

$$\frac{d^4 t(\xi)}{d\xi^4} - 4\varepsilon t^2 \frac{d^2 t(\xi)}{d\xi^2} - \varepsilon \sigma \frac{d^2 [t^4(\xi)]}{d\xi^2} = 0 \quad (8)$$

with boundary conditions (3), (7). After linearization of the equations and boundary conditions (7) relative to $\theta(\xi) = t(\xi) - 1$ the solution can be obtained in a closed form:

$$\begin{aligned} q(\xi) &= 2(1 - t_2) \frac{\varepsilon(t^2 + \sigma)}{lf(\sigma, l, \varepsilon)} \left\{ \exp(-k\xi) - \exp[-k(1-\xi)] \right\}, \\ \theta(\xi) &= \frac{1-t_2}{f(\sigma, l, \varepsilon)} \left\{ \frac{\sigma}{2l} \left(\exp(-k\xi) - \exp[-k(1-\xi)] \right) - \right. \\ &\quad \left. - \frac{\sigma}{2l} [1 - \exp(-k)] - \varphi(\sigma, l, \varepsilon) \xi \right\}. \end{aligned} \quad (9)$$

where

$$\begin{aligned}
 k &= 2\sqrt{\epsilon(l^2 + \sigma)}, \\
 f(\sigma, l, \epsilon) &= \sigma + \sigma/l + l^2 + l\sqrt{\epsilon(l^2 + \sigma)} - \\
 &\quad - \exp(-k) |\sigma + \sigma/l + l^2 - l\sqrt{\epsilon(l^2 + \sigma)}|, \\
 \varphi(\sigma, l, \epsilon) &= \sigma + l^2 + l\sqrt{\epsilon(l^2 + \sigma)} - \\
 &\quad - \exp(-k) |\sigma + l^2 - l\sqrt{\epsilon(l^2 + \sigma)}|.
 \end{aligned}
 \tag{10}$$

At values of the dimensionless parameter σ , characterizing the ratio of heat transfer in the honeycombs by radiation and heat conductivity, close to 0 and ∞ , we obtain correspondingly

$$t(\xi) = 1 - (1 - t_2)\xi$$

- the solution with disregard of radiation;

$$t(\xi) = 1 - \frac{1 - t_2}{2(1 + l)} - \frac{(1 - t_2)l}{1 + l}\xi$$

- the solution, in the case of a round cylindrical filler coinciding with the distribution found in [2] for temperatures in a cylindrical tube in the absence of heat conductivity and corresponding to the approximate solution of the classical Vlasov-Khottel problem [4, 5, 6].

Introducing the generally accepted concept of effective heat conductivity of a honeycomb filler in the direction of axis z :

$$\lambda_{\text{eff}} = \frac{QH}{FT_1(1 - t_2)}, \tag{11}$$

where Q - total heat flow arriving from the upper base of the cell onto the lower

$$\begin{aligned}
 Q &= -\lambda\delta L \frac{dT}{dz}(0) + c_0 T_1^4 \left\{ F - [1 - 4(1 - t_2)] \times \right. \\
 &\quad \times \int_0^1 \frac{1}{2} \exp(-2l\xi) LH d\xi - \\
 &\quad - \int_0^1 \left[1 + 4\theta(\xi) - \frac{1 - \epsilon}{\epsilon} q(\xi) \right] \frac{1}{2} \exp(-2l\xi) LH d\xi \Big\} = \\
 &= -\frac{\lambda\delta LT_1}{H} \frac{d\theta}{d\xi}(0) + 2Fc_0 T_1^4 \frac{q(0)}{\epsilon},
 \end{aligned}$$

we obtain for $\bar{\lambda}_{\text{eff}} = \frac{\lambda_{\text{eff}}}{\lambda}$ the expression

$$\bar{\lambda}_{\text{eff}} = 4 \frac{\delta}{H} (1 + \sigma/l) \frac{\varphi(\sigma, l, \epsilon)}{f(\sigma, l, \epsilon)}, \quad (12)$$

being determined by dimensionless parameters $\bar{\delta} = \frac{\delta}{H}, l, \sigma, \epsilon$.

In the case of little influence of radiation ($\sigma \approx 0$) or heat conductivity ($\sigma \rightarrow \infty$) formula (12) turns into formula

$$\bar{\lambda}_{\text{eff}} = 4\bar{\delta}l = \frac{\delta L}{F} \quad (13)$$

and

$$\bar{\lambda}_{\text{eff}} = 4\bar{\delta} \frac{\sigma}{1+l} = \frac{4c_0 T_1^3 H}{\lambda} \frac{1}{1 + \frac{LH}{4F}} \quad (14)$$

correspondingly; in the case of a radiating capacity of the filler close to 0 ($\epsilon \approx 0$) the effective heat conductivity of a honeycomb filler, as it should be expected, is determined by the sum of equations (13) and (14)

$$\bar{\lambda}_{\text{eff}} = 4\bar{\delta} \left(l + \frac{\sigma}{1+l} \right). \quad (15)$$

The solution of (12) makes it possible to select the form of the honeycomb filler cells which possess the least effective heat conductivity. When $\epsilon=0$ we obtain from (15) for the optimal magnitude of geometric parameter l :

$$\begin{aligned} l_{\text{opt}} &= \sqrt{\sigma} - 1 && \text{when } \sigma > 1, \\ l_{\text{opt}} &= 0 && \text{when } \sigma < 1. \end{aligned}$$

This and the analogous dependence of l_{opt} on σ when $\epsilon=1$, constructed according to (12), are shown in Figure 3.

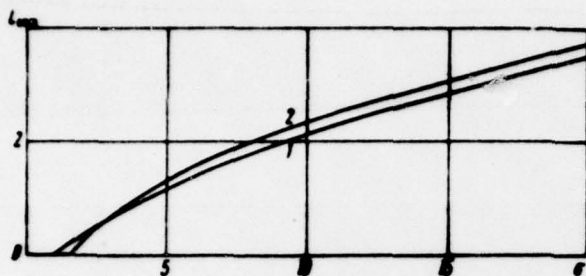


Figure 3. Dependence of l_{opt} on σ :
1 - when $\epsilon=0$; 2 when $\epsilon=1$.

DESIGNATIONS

T - temperature ($^{\circ}K$); z - coordinate on height of filler;
 $q_{рез}$ - density of resulting radiant heat flow; c_0 - Stefan-Boltzmann constant; λ , ϵ , H , δ - heat conductivity, degree of blackness, height and half-thickness of the filler wall; L , F - length of contour and area of cell base; D - diameter; a - distance between parallel walls; $\lambda_{эф}$ - effective heat conductivity of a honeycomb filler in the direction of axis z .

BIBLIOGRAPHY

1. Поварнищин М. С. ИФЖ, № 10, 1961.
2. Usiskin S. M., Siegel R. Journal of Heat Transfer, Nov., 1960.
3. Суринов Ю. А. Сб. «Теплопередача и тепловое моделирование». М., Изд-во АН СССР, 1959.
4. Власов О. Е. Известия ВТИ, № 1, 1929.
5. Якоб М. Вопросы теплопередачи. М., ИЛ, 1960.
6. Шорин С. Н. Теплопередача. М., изд-во «Высшая школа», 1964.

DISTRIBUTION LIST

DISTRIBUTION DIRECT TO RECIPIENT

<u>ORGANIZATION</u>	<u>MICROFICHE</u>	<u>ORGANIZATION</u>	<u>MICROFICHE</u>
A205 DMATC	1	E053 AF/INAKA	1
A210 DMAAC	2	E017 AF/RDXTR-W	1
P344 DIA/RDS-3C	9	E403 AFSC/INA	1
C043 USAMIIA	1	E404 AEDC	1
C509 BALLISTIC RES LABS	1	E408 AFWL	1
C510 AIR MOBILITY R&D	1	E410 ADTC	1
LAB/FIO		E413 ESD	2
C513 PICATINNY ARSENAL	1	FTD	
C535 AVIATION SYS COMD	1	CCN	1
C591 FSTC	5	ASD/FTD/NIIS	3
C619 MIA REDSTONE	1	NIA/PHS	1
D008 NISC	1	NIIS	2
H300 USAICE (USAREUR)	1		
P005 DOE	1		
P050 CIA/CRS/ADD/SD	1		
NAVORDSTA (50L)	1		
NASA/KSI	1		
AFIT/LD	1		
ILI/Code I-380	1		